Boosting the share of renewable energy by optimized scheduling of a heat pump using thermal mass of the building

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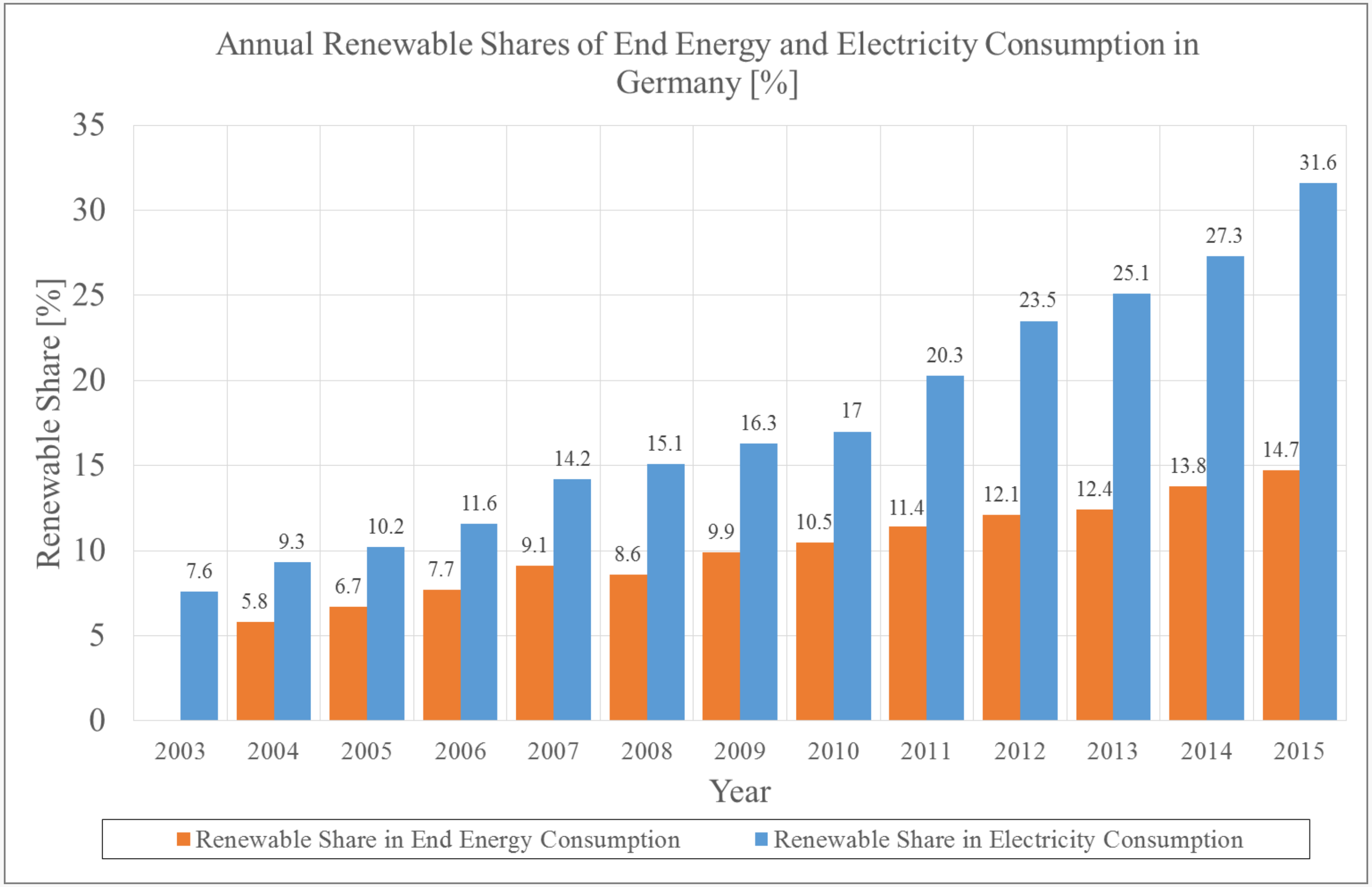
Agenda

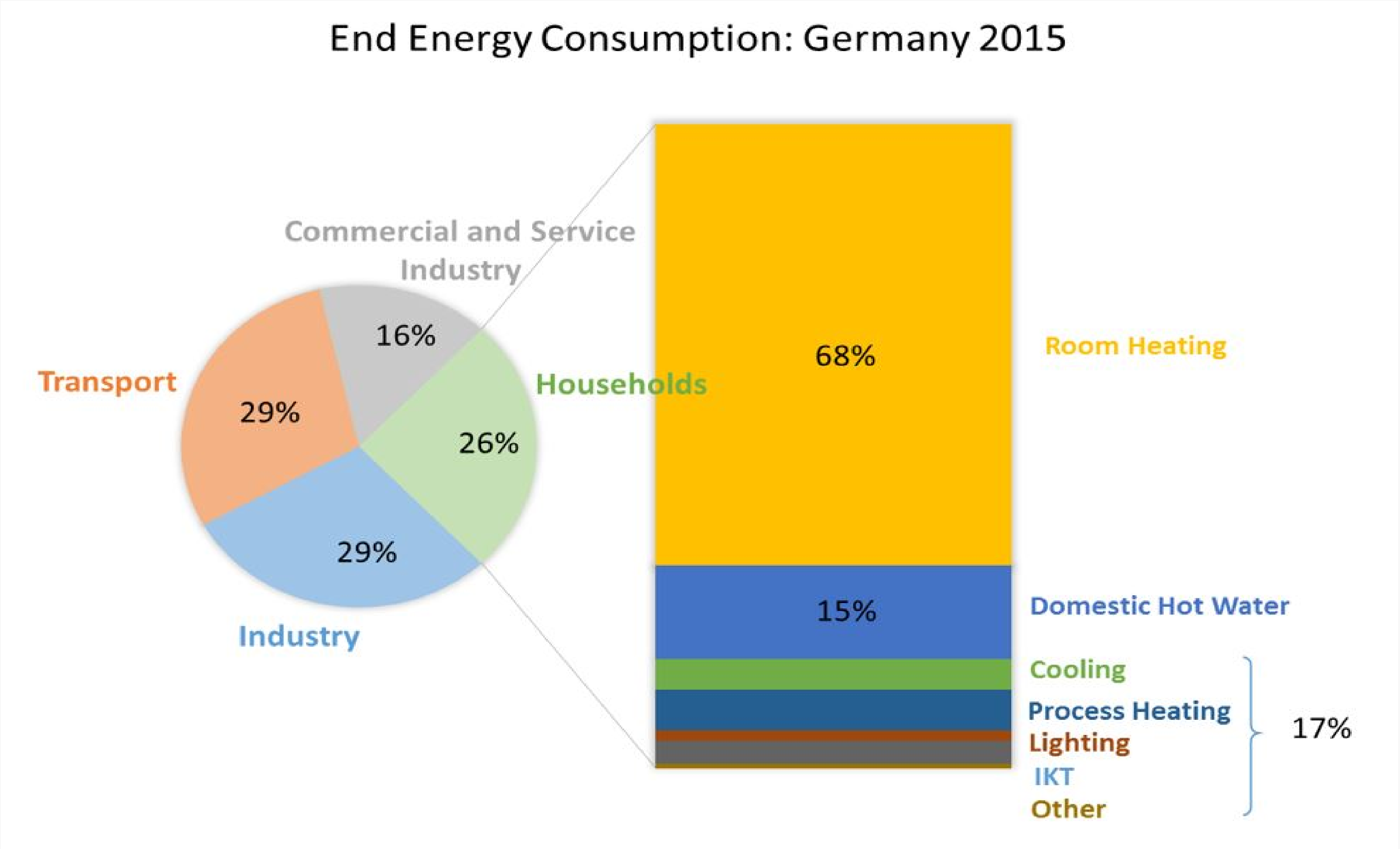
1. Problems and challenges
2. Heat pump: Two tank model
3. Optimization
4. Results
5. Conclusion

1. Problems and challenges



Data Source: Energiedaten, BMWi and Umweltbundesamt Germany

1. Problems and challenges



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1. Problems and challenges

- Share of renewables in electricity sector (2015)*: 31.6%
- Share of renewables in end energy consumption (2015)*: 15%

Challenge

To bridge the gap between share of renewables in electricity and end energy consumption

How ?

Coupling heat and electricity sectors

Example

Heat pump system with PV electricity!

*Data Source: Energiedaten, BMWi and Umweltbundesamt Germany

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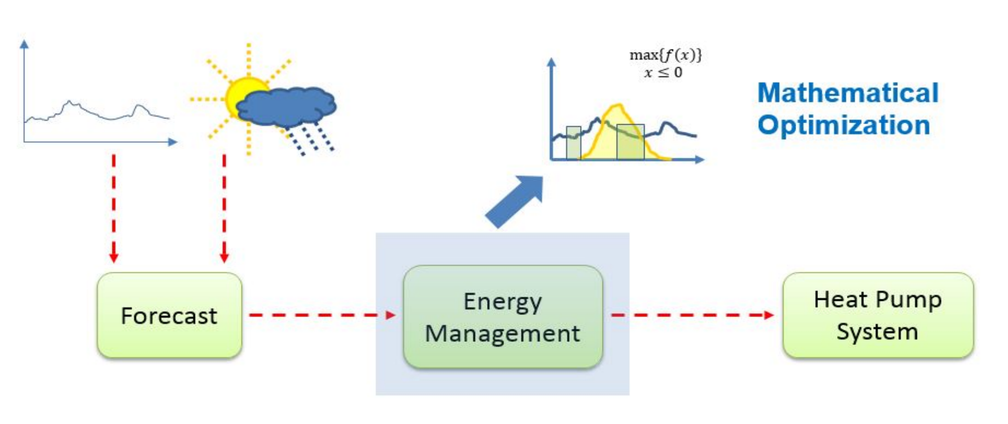
1. Problems and challenges

Current status:

Heat oriented operation of the heat pump: Uncontrolled electricity consumption



A controlled consumption of electricity and/or avoiding peak hour operations (Optimized operation)

Thermal Flexibility

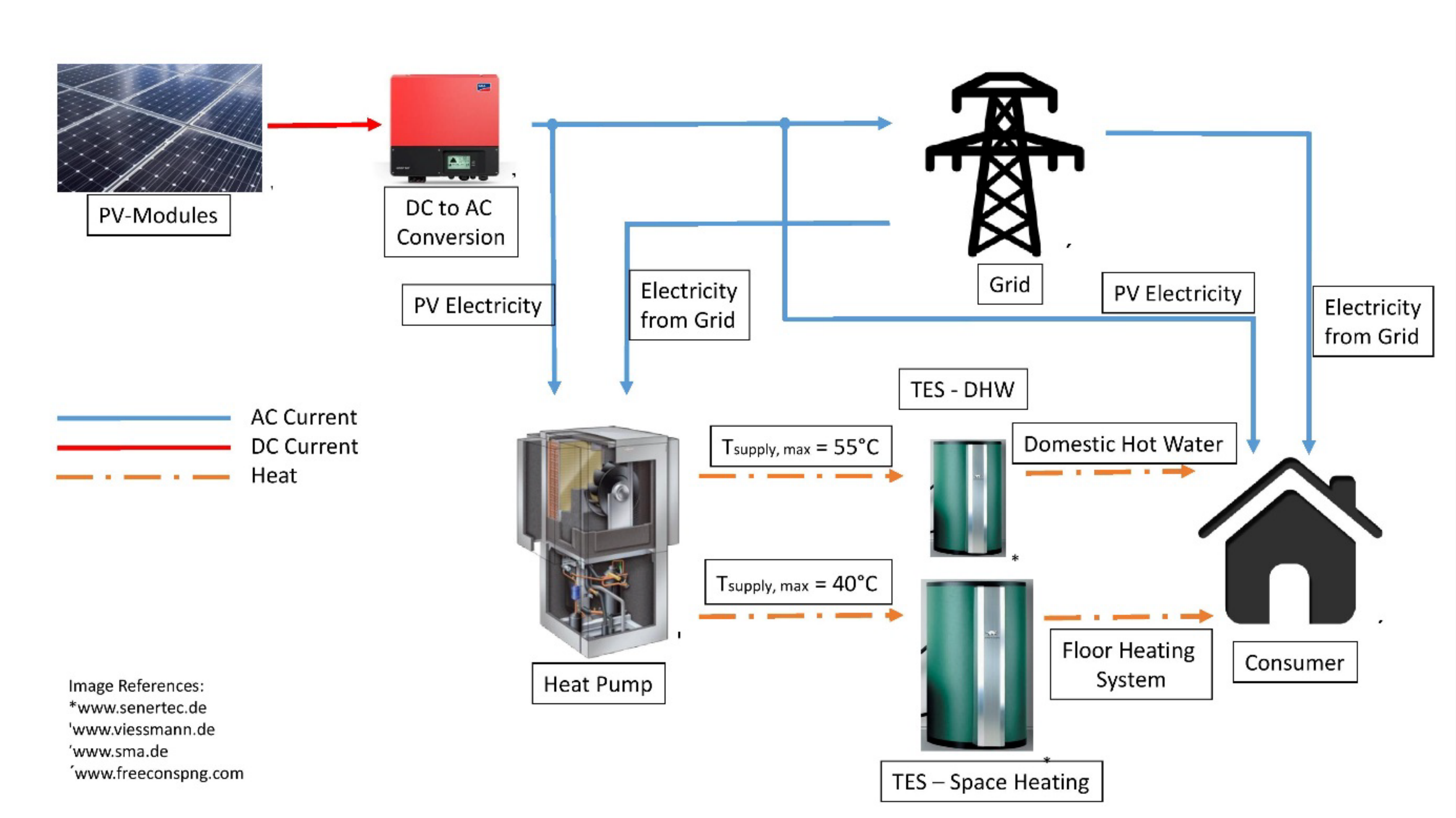
Electrical Flexibility

Thermal energy storages (TES)

Thermal storage capacity of the house

Cost and complexity (!)

2. Heat pump: Two tank model



2. Two tank model: Operational parameters

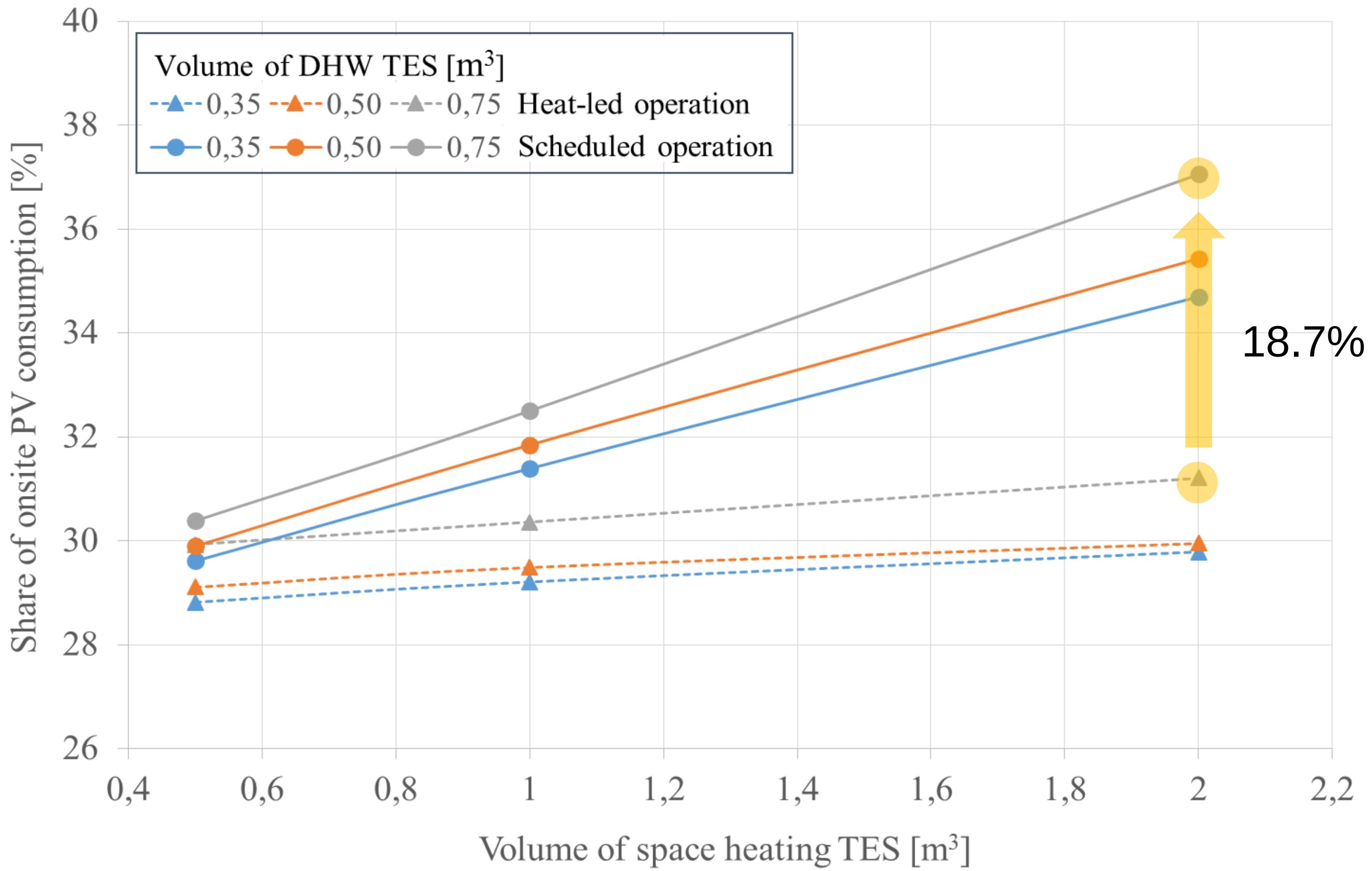
Consumption Data	
Yearly heat demand for space heating	19886 kWh
Yearly heat demand for DHW generation	2069 kWh
Yearly demand of electricity	3994 kWh
Energy Converters	
PV modules	10 kW, facing southwards
Heat pump	14 kW*

Optimization/Control:

- Daily Optimization for tuning the scheduling algorithm
- Yearly Optimization for deriving final performance data

*(B0/W35)°C

2. Two tank model: Background Simulations



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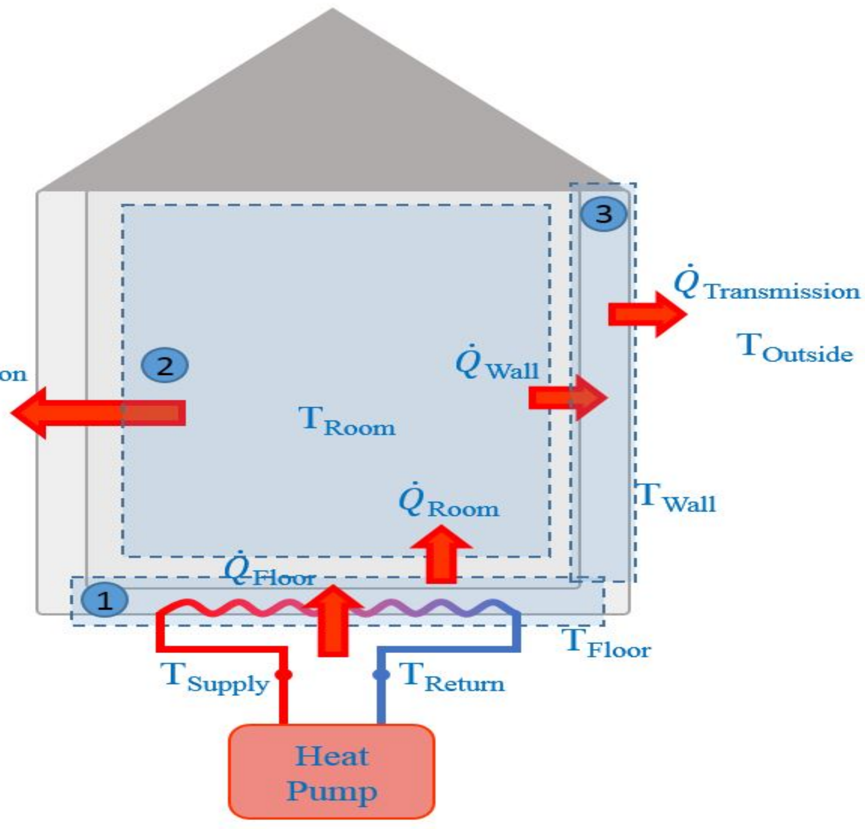
2. Two tank model: Thermal flexibility of the house

- Investigation of the effects of thermal flexibility of the house
- Floor heating model
- Room temperature control
- Weather based model

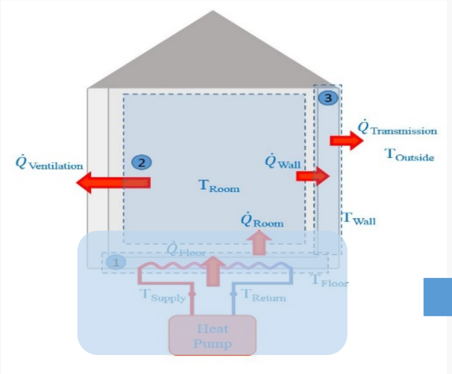
$$m_{Floor} \cdot c_{Floor} \cdot \frac{dT_{Floor}}{dt} = \dot{Q}_{Floor} - \dot{Q}_{Room} \quad (1)$$

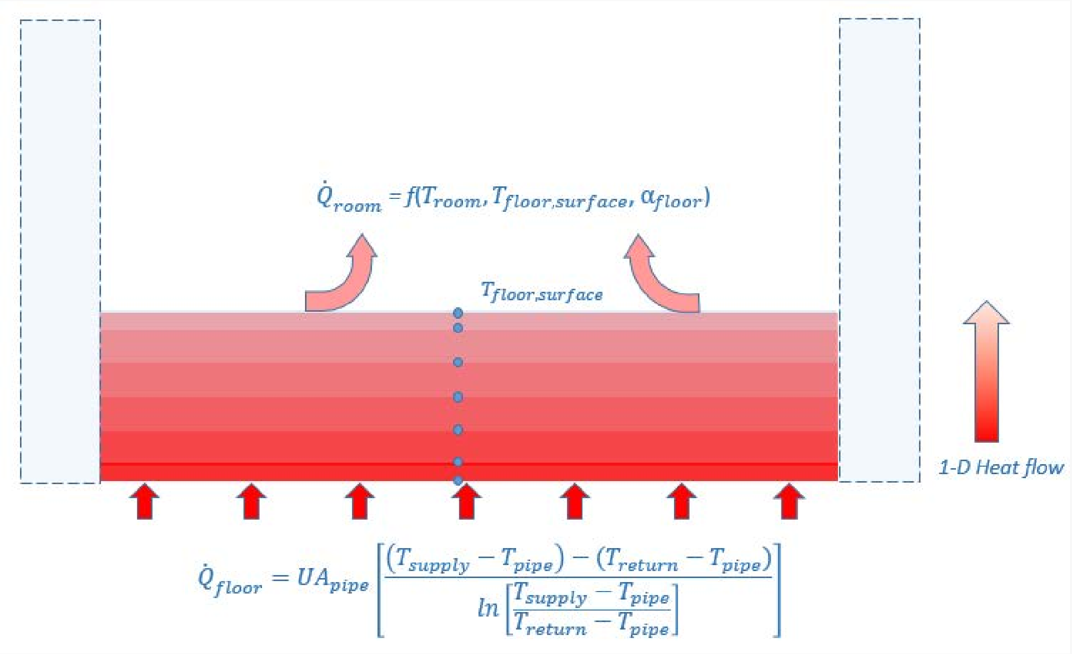
$$m_{Air} \cdot c_{Air} \cdot \frac{dT_{Room}}{dt} = \dot{Q}_{Room} - \dot{Q}_{Wall} - \dot{Q}_{Ventilation} \quad (2)$$

$$m_{Wall} \cdot c_{Wall} \cdot \frac{dT_{Wall}}{dt} = \dot{Q}_{Wall} - \dot{Q}_{Transmission} \quad (3)$$



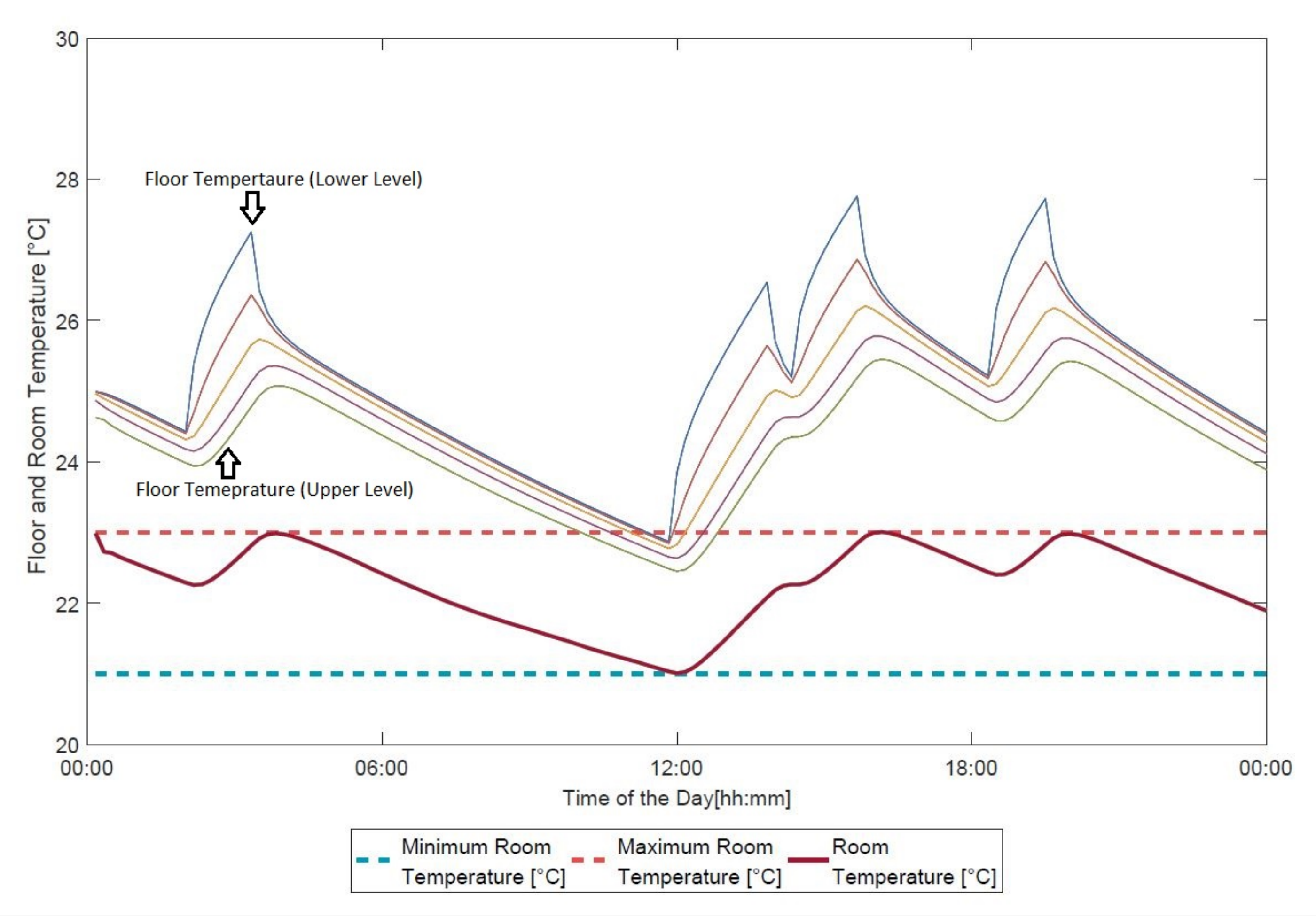
2. Two tank model: Temperature distribution of the floor



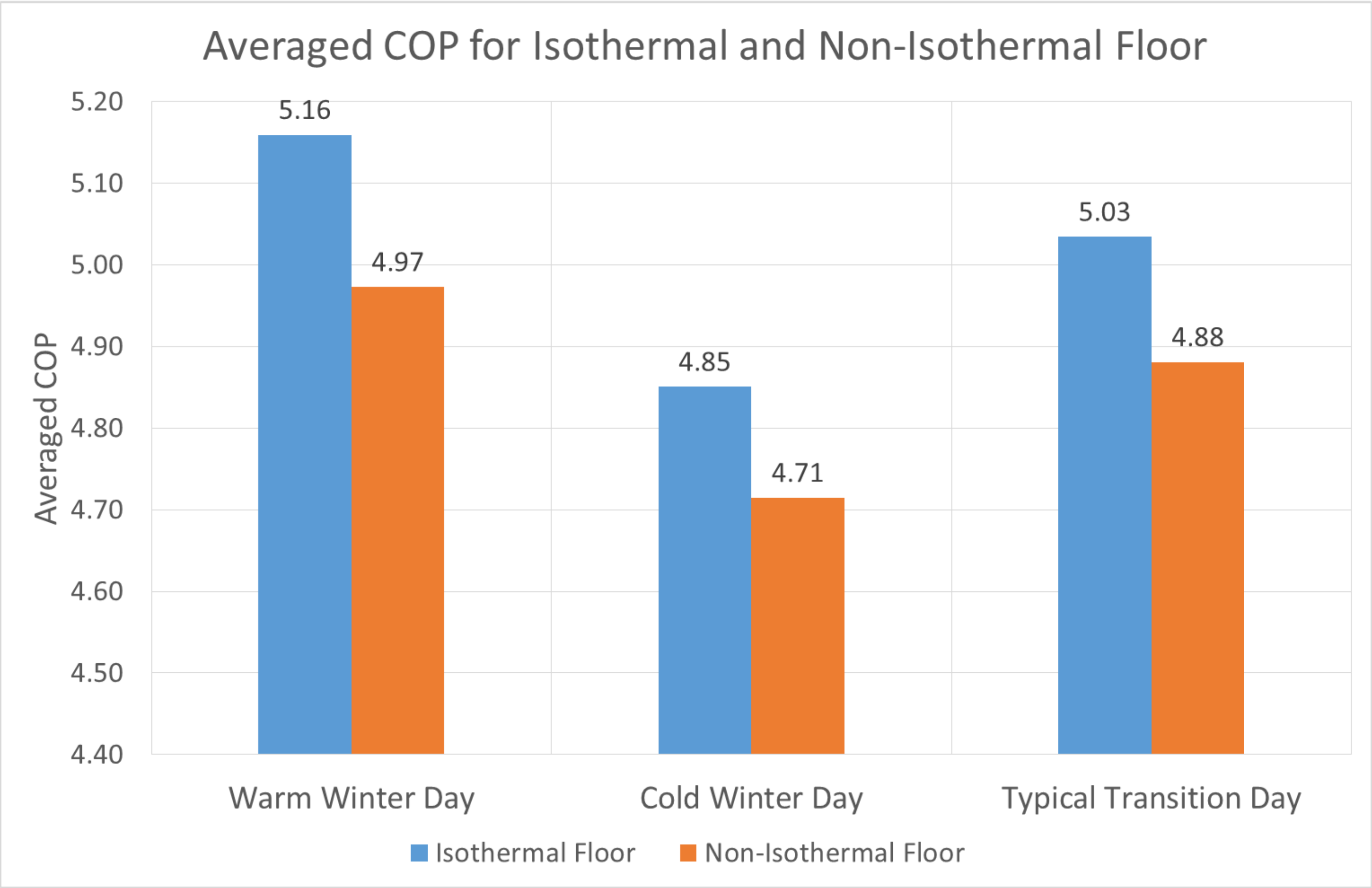


- Temperature distribution in the floor
- Calculations based on: Full-Implicit method
- Temperatures: Calculation of the heat flows

2. Two tank model: Temperature distribution of the floor

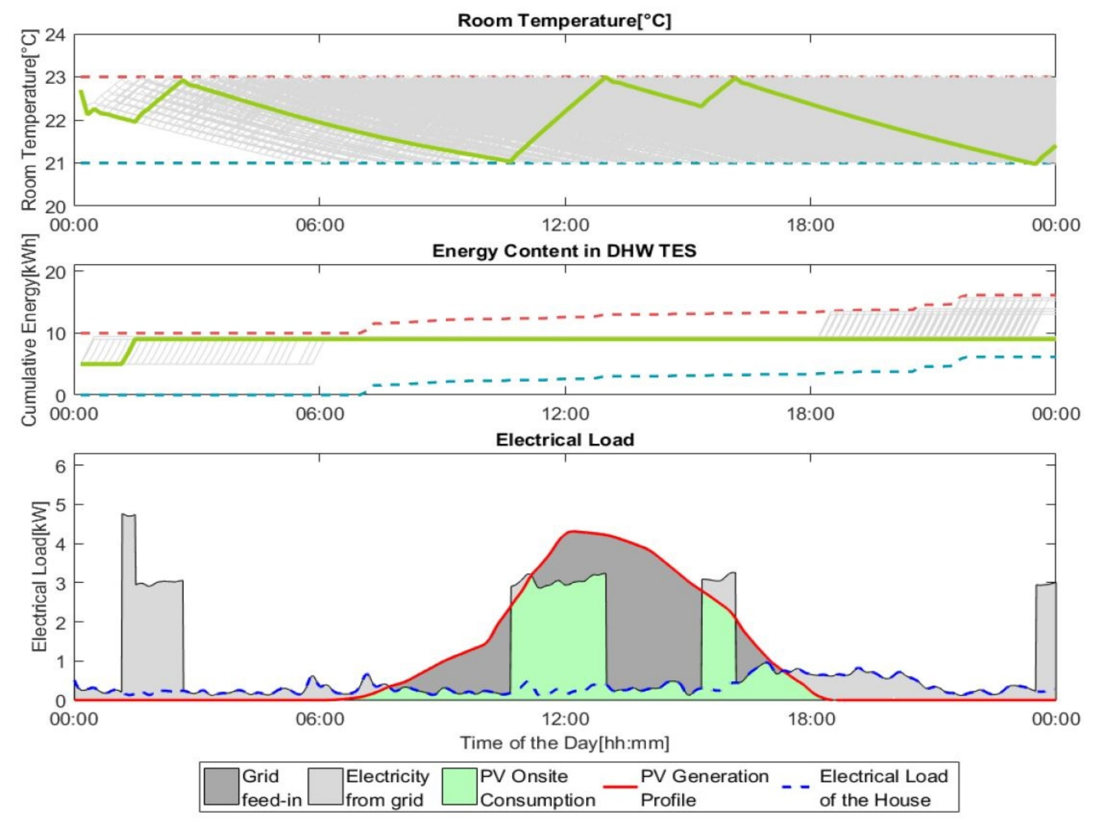


2. Two tank model: Isothermal and non-isothermal Floor

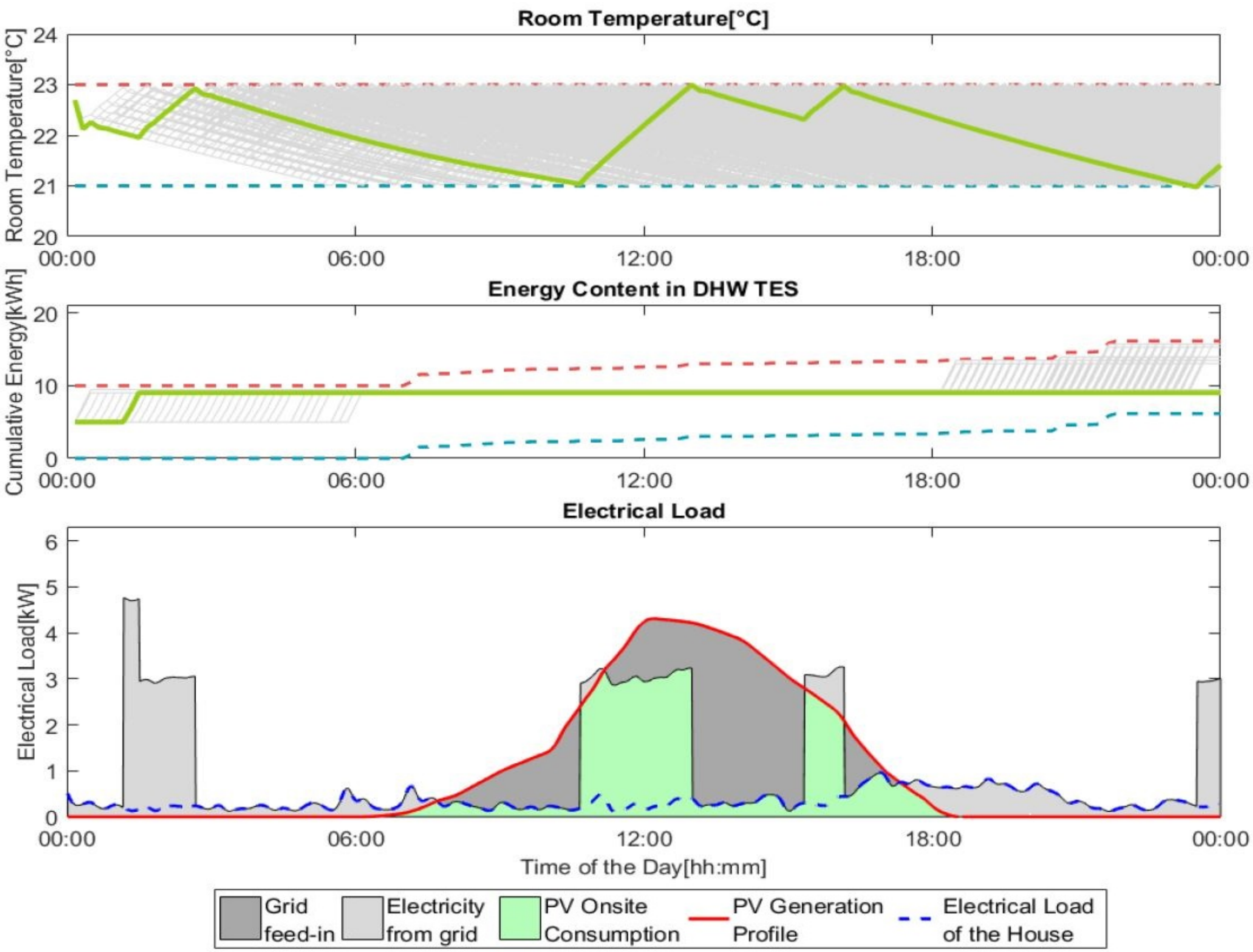


3. Optimization

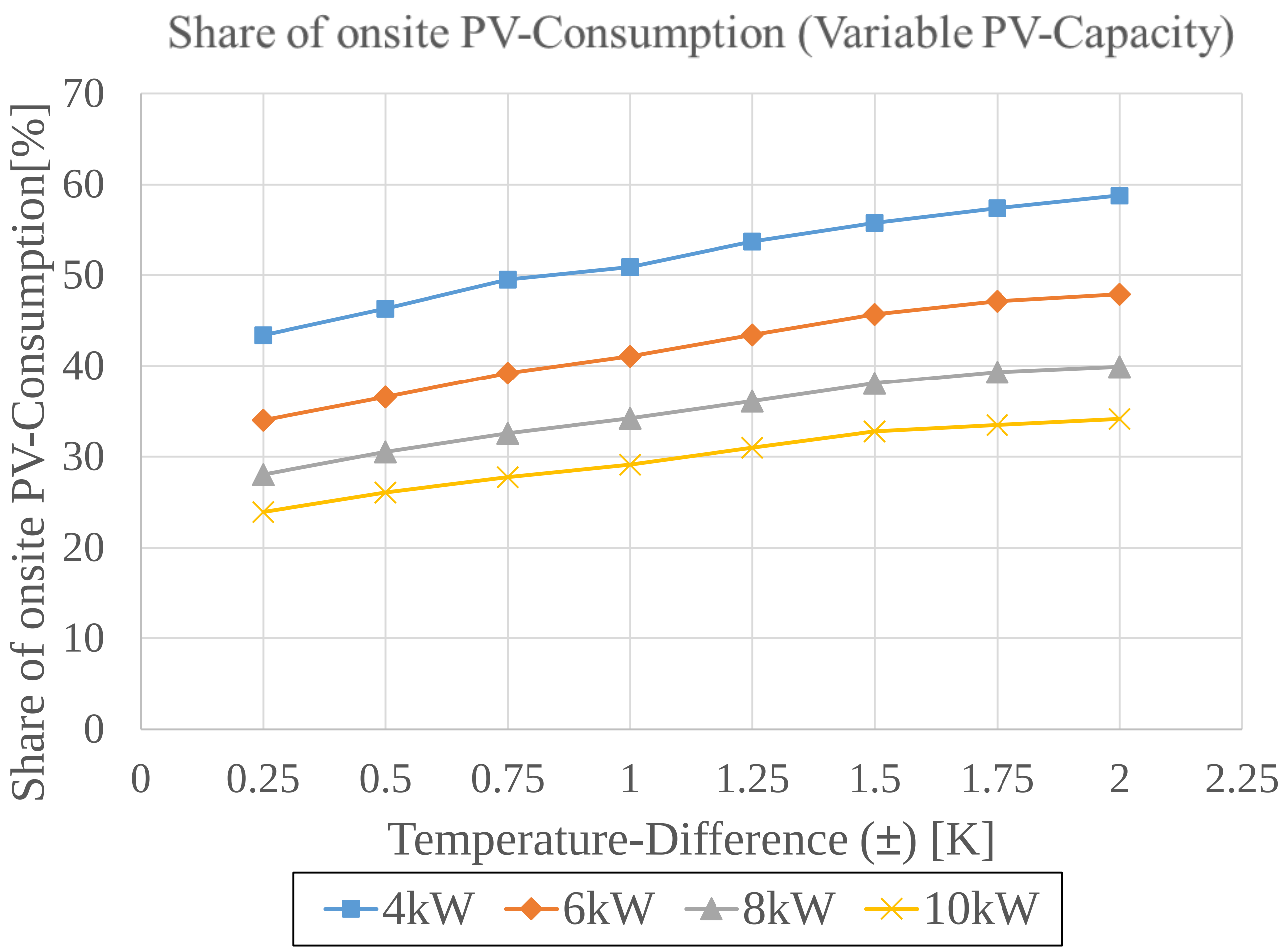
Heuristic optimization for room temperature control and energy content in DHW TES in MATLAB-Simulink



3. Optimization



4. Results: Onsite PV-Consumption



5. Conclusion

- Thermal energy storage shows potential to shift operation of the heat pump to times of higher PV-electricity generation (as compared to heat oriented operation)
- Size of thermal energy storage has to be very large, which is inconvenient in practice
- Thermal capacity of the house offers better flexibility as compared to the thermal energy storage
- Almost linear increase in share of onsite PV-consumption with increasing temperature difference and optimal sizing of PV-modules can be predicted
- Large size TES for space heating is avoided

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Thank you for your attention!

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